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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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INFORMATION CIRCULAR

MANGANESE

GENERAL INFORMATION

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ROBERT H. RIDGWAY

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MANGANESE[1]

GENERAL INFORMATION

By Robert Ridgway[2]

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INTRODUCTION

This circular outlines salient facts regarding the manganese-ore industry in the United States and the world. It is founded chiefly upon published information available in the literature of the subject. The Bureau of Mines has in its files additional, more detailed data upon many of the topics presented very briefly here, and will endeavor to assist the mineral industries and public by giving further information in response to individual inquiries. The Bureau will welcome comments, criticisms, and contributions of data that may assist in making later additions of this circular more accurate, or in developing more fully its mineral files pertaining to manganese.

In reporting the production of manganese-bearing ores in the United States the following classification has been adopted by the Bureau of Mines: (1) Metallurgical-grade ores, under which have been classified manganese ores containing 35 percent or more of manganese used in the manufacture of iron and steel, ferruginous manganese ore containing 10 to 35 percent of manganese, manganiferous iron ore containing 5 to 10 percent of manganese, and manganiferous zinc residuum; (2) battery ore; (3) fluxing ores, under which are classified ores that may contain a few ounces of silver and are rich enough in manganese to make them valuable chiefly for fluxing purposes in nonferrous smelters; and (4) miscellaneous ores, under which are classified the ores shipped to brick manufacturers, glass makers, and manufacturers of manganese chemicals.

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2 Mining engineer, common metals division U.S. Bureau of Mines.

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In this paper, however, only manganese ore containing more than 35 percent of manganese is considered. For the most part the report is interested in commercial high-grade ores that contain in excess of 45 percent of manganese and are suitable for the manufacture of ferromanganese. The ores mined in the U.S.S.R., India, Brazil, and the Gold Coast are of this quality and make up the bulk of the world consumption and trade in this type of ore. The ore produced in the Sinai peninsula, while of lower grade (30 percent), is of some significance and is given some consideration.

PROPERTIES OF MANGANESE

Manganese is a crystalline, brittle metal, silvery white or grayish white in color with a reddish luster. The specific gravity varies from 7.05 to 8.01, depending on the sample. Its atomic weight is 54.6; melting point, 1,244°D.; boiling point, 1,900°C.; electric conductivity as compared with silver, 1 to 55. Several different allotropic forms of the element are known to exist. To a sodium carbonate bead in an oxidizing flame, manganese imparts a characteristic bluish green color; to a borax bead in an oxidizing flame it gives a purplish or amethystine color. Its chemical properties are similar to those of iron. It oxidizes readily and consequently is never found in nature in the metallic state.

MANGANESE MINERALS

Manganese generally occurs in nature as an oxide, carbonate, or silicate, either alone or in combination with various metals. The oxides pyrolusite and psilomelane are the most important forms. The chief minerals of manganese are described below.

Pyrolusite (MnO_2, generally containing a little H_2O) forms the chief manganese ore. It has a metallic lustre and varies from grayish black to black in color. The mineral is soft and will soil the fingers; its hardness varies from 2 to 2.5 and specific gravity from 4.73 to 4.86. When pure, pyrolusite contains 63.2 percent manganese, but it is rarely found in the pure state; usually it contains small quantities of silica, lime, iron, and barite. The ore usually occurs massive or reniform, occasionally with a fibrous or radiate structure; sometimes it is found powdered or in small grains. The bulk of the Caucasian ore consists of pyrolusite.

Psilomelane (of uncertain composition, perhaps conforming to H_4MnO_5) is often associated with pyrolusite as an ore of manganese. It is iron black to dark steel-gray in color with a dull submetallic luster. It can be distinguished from other manganese oxides by its hardness, which varies from 5 to 6. Specific gravity ranges from 3.7 to 4.7. It is amorphous, the common form being rounded or botryoidal masses, usually with a smooth surface. The content of metallic manganese ranges from 45 to 60 percent. It is often associated with small quantities of barite and potash. Psilomelane is the most abundant mineral in the manganese ores found in India.

Braunite (M_2O_3, $MnSiO_3$, the sesquioxide and silicate of manganese) is invariably associated with silica either mechanically mixed or chemically combined, in amounts up to 8 or 10 percent. It is a brownish or grayish black mineral with a submetallic luster. The ore ranges in hardness from 6 to 6.5, and is frequently too hard to scratch with a knife. The specific gravity varies from 4.75 to 4.82. Braunite, which contains 69 percent metallic manganese, never occurs pure in nature; in ores it is usually associated with other manganese minerals, especially psilomelane. Braunite is a characteristic mineral in the manganese deposits of Arkansas, where it occurs with psilomelane.

Manganite ($Mn_2O_3.H_2O$, the hydrated sesquioxide) is sometimes known as gray manganese ore. Its color varies from steel-gray to iron-black with a submetallic luster. Its hardness is

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4 and its specific gravity 4.3. Manganite frequently alters to pyrolusite, from which it can be distinguished by its hardness and brown streak. Pure manganite contains 62.5 percent manganese. In the United States it is found mainly in California.

Hausmanite ($MnO.Mn_2O_3$) is a brownish black mineral with a dull metallic luster. Its hardness ranges from 5 to 5.5 and its specific gravity from 4.72 to 4.86. The manganese content is 72.1 percent. It is one of the rarer oxides of manganese, but is widely distributed and occurs with other manganese minerals. It is produced artifically by the sintering of carbonates and oxides.

Wad (impure hydrous mixture of oxides of manganese) is an amorphous, earthy, soft, friable mineral with a black or brown color and is commonly known as bog manganese.

Rhodochrosite ($MnCO_3$, carbonate of manganese) is a rose-pink mineral with a pearly luster and has a manganese content of 47.8 percent when pure. It has a hardness of 3.5 to 4.5, being easily scratched with a knife; specific gravity ranges from 3.45 to 3.6. It is a comparatively rare mineral and is usually found associated with other metals in vein deposits. It has been mined as a manganese ore in the French Pyrenees and at Butte, Mont.

Rhodonite ($MnSiO_3$, silicate of manganese) is a rose-colored mineral with a vitreous luster. Its hardness varies from 5.5 to 6.5, being somewhat greater than that of rhodochrosite; specific gravity ranges from 3.4 to 3.68. The content of metallic manganese is 42 percent.

Bementite ($2MnSiO_3.H_2O$, the hydrosilicate of manganese) is a soft mineral, pale grayish yellow to brown in color, with a pearly luster. Its specific gravity is 2.9. It is a common mineral in the deposits in the Olympic Mountains in the State of Washington.

Many other minerals contain varying amounts of manganese, but those just described represent the chief ores of manganese; the two silicates are of very minor importance.

MODE OF OCCURRENCE

Manganese is a common and widely distributed metal. It is very active chemically and is found in many mineral forms. Like iron, it is dissolved out of the crystalline rocks, in which it is almost invariably present, and is redeposited as carbonate, oxide, or hydroxide. The more common mineral compounds are the oxides, carbonates, and silicates. The manganese ores usually consist of a mixture of oxides and are generally of secondary origin, either residual or sedimentary. Of the few bedded deposits known, those at Tchiaturi are the best example. Small amounts of carbonates and silicates have been mined for their manganese content in a few places.

The manganese deposits of the United States have been classified according to their form by the U.S. Geological Survey[3] as follows:

1. Stratiform masses:
   - (a) Oxides interlayered with sediments or layered volcanic or metamorphic rocks.
   - (b) Carbonates or silicates interlayered with sediments or layered volcanic or metamorphic rocks.
   - (c) Oxides, as surface bog deposits.
2. Veins and breccia filling:
   - (a) Oxides in larger part.
   - (b) Carbonates or silicates partly weathered to oxides.
3. Irregular masses:
   - (a) Oxides.
   - (b) Carbonates or silicates largely weathered to oxides.

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3 Hewett D. F., Manganese and Manganiferous Ores in 1918: U.S. Geol. Survey, Mineral Resources of the United States, 1918, pt. 1, 1920, pp. 641-642.

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4. Aggregates of small oxides in clay or weathered rocks:
   (a) Mainly oxides.
5. Unclassified deposits.

According to their genesis there are two types of deposits: Namely, primary and secondary. The minerals that commonly make up the primary deposits include the following, arranged approximately in order of their importance: Rhodochrosite, siderite, and the related group of carbonates of manganese, iron, calcium, and magnesium; rhodonite; spessartite; tephroite, and other silicates; and alabandite.

Secondary deposits of manganese commonly contain psilomelane, manganite, pyrolusite, braunite, and wad.

WORLD SOURCES

Although the ores of manganese are widely distributed throughout the world, occurrences of large bodies of high-grade ore of commercial importance are limited at present to Brazil, British India, the Gold Coast, the Union of South Africa, and the U.S.S.R. The less important occurrences of high-grade ore include those of Algeria, Austria, Canada, Chile, China, Costa Rica, Cuba, Czechoslovakia, England, Italy, Japan, Mexico, Morocco, Netherland East Indies, New Caledonia, Newfoundland, Panama, Portugal, Puerto Rico, Rumania, Spain, Sweden, Tunisia, and the United States. Lower-grade ores (ferruginous manganese ores) are obtained chiefly from Egypt, the United States, Germany, France, Greece, Italy, and Australia.

Russia

Manganese ores are widely scattered throughout Soviet Russia. However, at the present time the principal producing regions are Chiaturi and Nikopol. A much smaller production comes from the Urals.

Chiaturi.- The deposits at Chiaturi are located on the southern slope of the central part of the Caucausus Mountains about 100 miles east of the Black Sea port of Poti. The mines are centered about the village of Chiaturi in the Province of Kutais, District of Sharopan. The ores at Chiaturi are of sedimentary origin, and the deposits are distinctly stratified. They occur at the base of the Eocene in a regular and continuous horizontal bed ranging from 3 to 10 feet and averaging 7 feet in thickness. The deposit is extensive and exploitation has taken place over 17 square miles, which is divided into seven plateaus by the Kvirila River and its tributaries. The ore deposits are separated by deep valleys and occur at heights of from 500 to 700 feet above the bottoms of the valleys. The ore, which is soft and friable, consists mainly of pyrolusite, but psilomelane and wad are also present. Although production has been continuous since 1879, from the point of view of available tonnage the district still contains large quantities of ore. Estimates as to the extent of reserves differ, but in 1931, Markov estimated that there remained in the beds 72,994,000 metric tons of crude ore which will yield after washing and grading 41,397,000 tons of concentrates with a manganese content of 50 to 53 percent.

Mining is accomplished by underground methods; easy access to the ore is provided by the numerous openings along the outcrops. The ore is transported from the openings to the valley floor either in carts or by aerial tramway. Some of the ore is shipped directly without treatment, while the rest is sorted or washed to increase the manganese content.

The chief source of the Soviet manganese exports is the Chiaturi district which is connected by railroad to the Black Sea port of Poti. The analysis of the ores exported from the Chiaturi district in 1931 has been given[4] as follows:

4 Metalborse, Von Russischen Manganerz Export: Vol. 22, No. 22, 1932, p. 340.

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Analysis of Chiaturi manganese ore exported in 1931, percent

	Manganese	Silica	Phosphorous	Iron
Washed ore....	52	8	0.16	0.95
Ordinary ore	49.6	10.32	.17	1.15

Nikopol.- The most important manganese producing district in southern Russia is at Nikopol, Government of Ekaterinoslav, in the Soviet Republic of Ukraine on the Dnieper River about 100 miles above its entrance into the Gulf of Odessa. There are two main producing regions in the district, one to the northwest of the city of Nikopol in the vicinity of Pokrovsk and the other, known as Vostochny, to the northeast of Nikopol along the Tomakovk river near the villages of Gorodishcke and Krasnogrigorievka. The ore occurs in Oligocene strata as nodules of pyrolusite and psilomelane in a horizontal bed of sandy clay which is near the surface and which ranges from 3 to 5 feet in thickness. The greater part of the ore consists of pyrolusite. The mines are worked by underground methods through shallow shafts. The ore contains from 28 to 33 percent of manganese, but a much higher grade of concentrate is obtained by elimination of about 45 percent of the material mined. Concentration is effected by means of jigs in the eastern district and by dry breaking, screening, and cobbing in the western district. Although the concentrates produced are higher in silica and phosphorous than those produced at Chiaturi, they are good for metallurgical use because of their being clean and coarse.

The following are typical analyses of Nikopol concentrates:

Analysis of Nikopol concentrates, percent

District	Mn	SiO_2	P	Fe
Pokrovsk	42-46	12-16	0.2-.03	0.3-0.7
Vostochny (eastern)	47-52	8-10	0.17	0.3-0.7

The ore reserves at Nikopol have been estimated at different times to be from 7,500,000 tons to 100,000,000 tons. The following table shows the reserves in 1925 as estimated by E. K. Fuchs:

Ore reserves at Nikopol as of 1925

	Area,	Thickness,	Reserves, metric tons			
District	hectares	meters	Actual	Probable	Possible	Total
Pokrovsk	11,373	0.5-1.5	1,687,000	7,698,000	13,759,000	23,144,000
Vostochny	3,172	0.8-3.5	10,418,000	21,228,000	21,605,000	53,251,000
Total....	14,545	-	12,105,000	28,926,000	35,364,000	76,395,000

Being somewhat closer to the Soviet metallurgical centers, these deposits furnish practically all of the ore consumed in Soviet Russia, and as a consequence are of first importance to the home industry. Some of the ore, however, is exported, most of it going to Germany who draws largely on this deposit for her needs of manganese. The exported ore is of two different types; one type containing 48 percent Mn and the other containing 42 percent Mn. The analysis of the ores exported from the Nikopol district in 1931 has been given[5] as follows:

5 Metalborse, Von Russischen Manganerz Export: Vol. 22, No. 22, 1932, p. 340.

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Analysis of Nikopol manganese ore exported in 1931, percent

	Manganese	Silica	Phosphorous	Iron
First grade	48.43	8.84	0.18	1.30
Second grade	42.75	14.46	.19	1.90

The district is connected by rail to the Black Sea port of Nikolayev about 200 miles distant.

Other Deposits.- There are numerous other deposits in the Urals and Siberia, but only four or five are being exploited and their entire output goes to Russian furnaces. Recent reports indicate that production has been started at the deposits on the Mazul river, a few miles south of Achinsk in Siberia. It is said that the new mines will be able to satisfy the entire demand of the Stalinsk steel plant at Kuznetsk which formerly was to have used Chiaturi ores.

India

There are many known occurrences in India containing large reserves of commercial ore. The principal deposits are in the Balaghat, Bhandara, Chhindwara, and Nagpur districts of the Central Provinces. The producing deposits are of three types described as gondite, kodurite, and lateritoid.[6] In the gondite type the orebodies occur as lenticular masses and bands intercalated with quartzites, schists, and gneisses derived from metamorphosed pre-Cambrian manganese sediments. The orebodies often attain great dimensions, even up to 6 miles in length. The bulk of the ore produced in India, as well as the highest-grade ore, comes from this type of deposit.

The kodurite type of deposit consists of orebodies of irregular size and shape associated with Archean crystalline rocks. Some believe these deposits to be of igneous origin while others suggest that they represent the assimilation of manganese orebodies in an acid magma. They are developed typically in the Vizagapatam district where manganese ore was first mined in India. To date more than 1,000,000 tons have been produced in this district. The ores are usually second and third grade.

The lateritoid deposits consist of irregular masses of iron and manganese ores occurring on the outcrops of pre-Cambrian rocks. The ores are characterized by high iron, low silica, and low phosphorous content and are usually classified as low-grade manganese ores and ferruginous manganese ores.

Fermor gives the locality of the deposits of the various types as follows, the underscored names indicating deposits from which ore has been exported:

(a) Gondite type-
Bihar and Orissa:- Gangpur
Bombay:- Narnkot, Panch Mahals, Chhota Udepur
Central India:- Jhabua
Central Provinces:- Balaghat, Bhandara, Chhindwara, Nagpur, and Seoni

(b) Kodurite type-
Madras:- Ganjam, Vizagapatam

(c) Lateritoid type-
Bihar and Orissa:- Keonjhar, Singhbhum
Bombay:- Dharwar, North Kanara, Ratnagiri
Central Provinces:- Jubbulpore

6 Fermor, L. L.. Manganese: Rec. Geol. Survey of India, vol. 64, 1930. pp. 172-233.

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Goa
Madras:- Bellary, Sandur
Mysore:- Chitaldrug, Kadur, Shimoga, Tumkur

Most of the ore is extracted from open pits and is usually of direct shipping grade. Hand sorting is resorted to in order to increase the manganese content, but there is no mechanical concentration of the product. An important factor in the Indian manganese industry is the cost of transportation. Most of the production comes from the Central Provinces and must be hauled long distances by rail to Bombay or Calcutta at considerable cost. New railway lines have been and are being constructed and the harbor of Vizagapatam is being improved in order materially to shorten the rail haul on the bulk of the Indian manganese output.

Although no new areas containing manganese have been discovered in recent years, the reserves of manganese ore are still extensive.

There is some consumption of manganese ore in India, where it is used in the making of ferromanganese and in steel manufacture. In 1929 47,435 long tons were consumed and in 1930, 46,099 tons were consumed.

Brazil

Manganese ores are widely distributed in Brazil, but the principal deposits of commercial importance are in the State of Minas Geraes. Deposits also occur in the States of Bahia, Matto Grosso, Maranhao, Parana, Pernambuco, Rio de Janeiro, Rio Grande do Norte, Santa Catharina, Cerra, and Sao Paulo. With the exception of Bahia, where some mining has taken place, none of these deposits appears to have been actively mined. Enormous reserves are reported to exist in Matto Grosso, but the distance from seaboard has hampered their development.

The deposits in Minas Geraes are in the central part of the state and include the producing districts of Queluz-Lafayette and Burnier-Ouro Preta. Both districts are connected to Rio de Janeiro by rail, the former being 287 miles north and the latter 317 miles north of this port.

The deposits of Minas Geraes are of two classes, one occurring as beds in metamorphosed sediments of Huronian age associated with iron ore, and the other as lens-shaped bodies in schistose rocks and granite of Laurentian age. Deposits of the second class are residual. The ores of the Burnier district, which are powdered and soft, belong to the first group, while ores of the second group, which are spongy and hard, are found in the Queluz district. The principal minerals are psilomelane, pyrolusite, and manganite. Mining is accomplished chiefly by open-cut methods, although some ore is extracted from underground workings. Practically no machinery is used in mining the ore. Some small washing plants are used but at the largest producing mine no special treatment is given to improve the grade of the ore.

The principal producing mine in Brazil is the Morra da Mina or Merid mine in the Queluz district. The ore, largely psilomelane, is compact and is mined from open cuts. It averages 48 to 51 percent manganese, 5 to 8 percent iron, 3 to 4 percent silica and 0.10 percent phosphorous. Reserves are estimated at 10,000,000 tons of ore. During 1932 this property suspended operations because of lack of market and low prices of ore.

Gold Coast

Although manganese ore is widely distributed in the Gold Coast, only one deposit of major economic importance has been developed to date. It is located along the Sekondi-Kumasi Railway at Dagwin near Taquah in the Gold Coast Colony. The orebodies occur in

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ancient sedimentary and metamorphic rocks along a ridge about 2½ miles long. Large amounts of detrital material are also found along the edge of the main ridge. The predominating mineral is psilomelane. All of the production comes from the Nsuta mine of the African Manganese Co., Ltd., at Nsuta, Western Province. The Nsuta mine is probably the largest manganese mine in the world. The ore is removed from open cuts by steam shovels and is hauled to washing plants in steam trains. All of the ore is crushed and washed in log washers, and recovery averages 92 percent. The concentrates of metallurgical grade average 50 to 53 percent manganese, 2 to 4 percent iron, 3 to 7 percent silica, and 0.1 to 0.12 percent phosphorous. The mine also produces chemical-grade ore of good quality. The extent of the reserves has not been ascertained, but there is considered to be 10 million tons of ore in sight.

Regarding the origin of the manganese deposits on the Gold Coast, Junner[7] has this to say, in part:

> The question of the origin of these ores is of considerable economic importance, for if they were formed, as is maintained by certain observers,[8] by the action of descending superficial waters on original sediments containing a relatively small percentage (1 to 20 percent) of manganese, causing the leaching and removal of silica and alumina, etc., from the rock and the leaching and deposition of the manganese in concentrated form, then it is obvious that the extension in depth of workable deposits will be strictly limited.
>
> From his study of the Nsuta ores the writer believes that they represent ancient (pre-Cambrian?) deposits of high-grade manganese ores which in general have not been modified greatly by vadose waters in recent geological times and that where the structural features are favorable the ores are likely to persist in depth.

The extensive reserves and the ease with which the ore of this deposit may be mined and transported to seaboard, makes this source an important factor in the world supply of manganese.

Union of South Africa

The Union of South Africa has never been an important factor in the world's production of manganese, but developments there during the last 5 years warrant its consideration as a potential producer of magnitude. Its advent into the world markets has been delayed by the serious curtailment of steel production but with the return of more normal conditions, production may be of importance.

The principal deposit is in the Postmasburg district in the northern part of the Cape Province about 108 miles west-northwest of Kimberley and about 65 miles northwest of the railhead at Koopmansfontein, from which a branch line has been built to serve the manganese area. The manganese ore occurs as an impersistent layer, or sheet, from 5 to 20 feet in thickness, outcropping at frequent intervals along the crest of a ridge which extends 47 miles in a northerly direction from a point about 5 miles west-northwest of Postmasburg. Psilomelane is the predominant mineral.

The ore, which is hard and contains very little fines, is of high grade, and shipments to industrial consuming centers have been favorably received. It is classified into three grades, the first class containing 51 percent, the second class 48 percent and the third class 44 percent of manganese. The various grades can be recognized and segregated by work-

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7 Junner, Dr. R. N., Report on the Geological Survey Department, 1930–1931, Gold Coast Colony: Aera, 1931, p. 4.

8 Bishop, D. W., and Hughes, W. T., A Contribution to the Geology of the Manganese-Ore Deposits in the Gold Coast Colony and in Ashanti: Trans. Inst. Min. and Met., vol. 39, London, 1930, p. 142–191.

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ers at the mine. Although the deposit has been opened up in a number of places, mining is not yet extensive, as there is a considerable amount of rubble ore scattered about the ground. The deposit can be worked cheaply by open-pit methods; the main cost item is likely to be the long rail haul to the seacoast at Durban.

The reserves are extensive and are estimated by some to be as high as 1,000,000,000 tons. The deposits were discovered in 1925, and have been under investigation since 1926. In 1930 the railroad was extended from Koopmansfontein to the deposit. Production began in 1930 but in the last half of 1931 operations were discontinued because of low prices and lack of market.

Egypt

The most important manganiferous area in Egypt is found in the hills of the Um Bogma district, about 19 miles southeast of the Red Sea port of Abou Zenima and about 70 miles south of Suez. The manganese deposits occur irregularly in more or less horizontal bedlike formations below carboniferous limestone. The deposits vary in thickness from 6 inches to 12 feet. They are irregular in size and shape and the ore, which is fairly constant, in combined metal content, varies greatly in relative quantities of iron and manganese, so that the maintenance of a regular grade of ore requires constant attention. Most of the ore is of low grade, averaging 28 to 32 percent of manganese but occasionally running as high as 35 percent. It also contains about 25 percent iron with low percentages of silica, phosphorous, and alumina. This ore is not used extensively in the manufacture of ferromanganese but is consumed largely for the manufacture of basic pig iron in Europe, where it is mixed with the minette iron ores of Alsace-Lorraine.

The ore is mined by underground methods and is shipped without being washed. The ore reserves have been given as in excess of 2,500,000 long tons of assured ore, 3,070,000 tons of probable ore, and 6,274,000 tons of possible ore. Early in 1932 the mines suspended operations until the accumulated production of the last 2 or 3 years has been disposed of.

Cuba

Manganese ore is found in Cuba in Oriente, Santa Clara, Pinar del Rio and Mantanzas provinces, but only in Oriente does it occur in large commercial quantities. Most of the deposits are of low grade and have a high silica content; manganese is usually present as a mixture of pyrolusite, psilomelane, manganite, and wad.

Cuba has never been an important factor in the world market, but its position inside the United States tariff wall has stimulated exploration and research into this island's manganese resources to such an extent that Cuba may become a more potent factor in the United States market. The main development of note is that of the Cuban American Manganese Corporation which controls extensive deposits near Cristo, Province of Oriente, 10 miles north of Santiago on the mainline of the Cuban Railroad. As the ores are not of direct shipping grade, the company has constructed a mill capable of treating 350,000 tons of ore annually and producing 125,000 tons of high-grade concentrates containing 50 percent of manganese. The concentration process involves grinding, flotation, and sintering. The plan also calls for the production of manganese sulphate from the middlings and tailings.

United States

The production of manganese ore in the United States is not important when considering the world output; nor is it significant in magnitude when compared with domestic consumption.

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The available reserves of high-grade ore are small and the mining of many deposits on a large scale has been prevented by difficulties of technology or transportation. Manganese-ore deposits of the United States, though small, are widespread. Shipments of manganese ore from 19 States have been reported to the Bureau of Mines during the last decade. The location of these deposits is shown in figure 1, which also contains a diagram depicting the relative importance of the principal producing States during this period. Further details regarding the domestic production are shown in table 1:

Table 1.- Shipments of manganese ore (exclusive of fluxing ore) in the United States by kinds and States for the decade 1922-1931, inclusive, long tons

State	Battery-grade ore	Metallurgical manganese ore	Total manganese ore	Percent of total manganese ore
Alabama	-	4,208	4,208	0.8
Arizona	-	13,939	13,939	2.8
Arkansas	-	33,239	33,239	6.6
California	-	3,493	3,493	.7
Colorado	-	8,443	8,443	1.7
Georgia	-	40,620	40,620	8.1
Idaho	30	6,652	6,682	1.3
Massachusetts	-	35	35	.0
Montana	153,897	170,003	323,900	64.2
Nevada	-	6,631	6,631	1.3
New Mexico	-	15,940	15,940	3.2
North Carolina	-	142	142	.0
Oklahoma	-	33	33	.0
Tennessee	-	4,342	4,342	.9
Texas	-	444	444	.1
Utah	-	165	165	.0
Virginia	8,467	17,231	25,698	5.1
Washington	-	16,275	16,275	3.2
West Virginia	-	29	29	.0
Total	162,394	341,864	504,258	100.0

During the decade ending December 31, 1931, there was produced in the United States 504,258 long tons of manganese ore containing in excess of 35 percent of manganese. Of this total 162,394 tons or 32 percent was produced for consumption by the battery trade. Although there is a small demand for domestic ores in other uses both chemical and metallurgical, virtually all of the remaining 341,864 tons was used by the ferrous metallurgical industries, 256,000 tons or 51 percent of the total having been consumed in the manufacture of ferromanganese alone.

Montana has been the principal source of both domestic battery-grade ore and domestic metallurgical manganese ore, more than 64 percent of the total production coming from that State. The battery-grade ore came entirely from Philipsburg, where it is produced as a magnetic concentrate made from ores mined in this district. Such concentrates average about 72 percent manganese dioxide. The rhodochrosite ore, which contains 35 to 37 percent of

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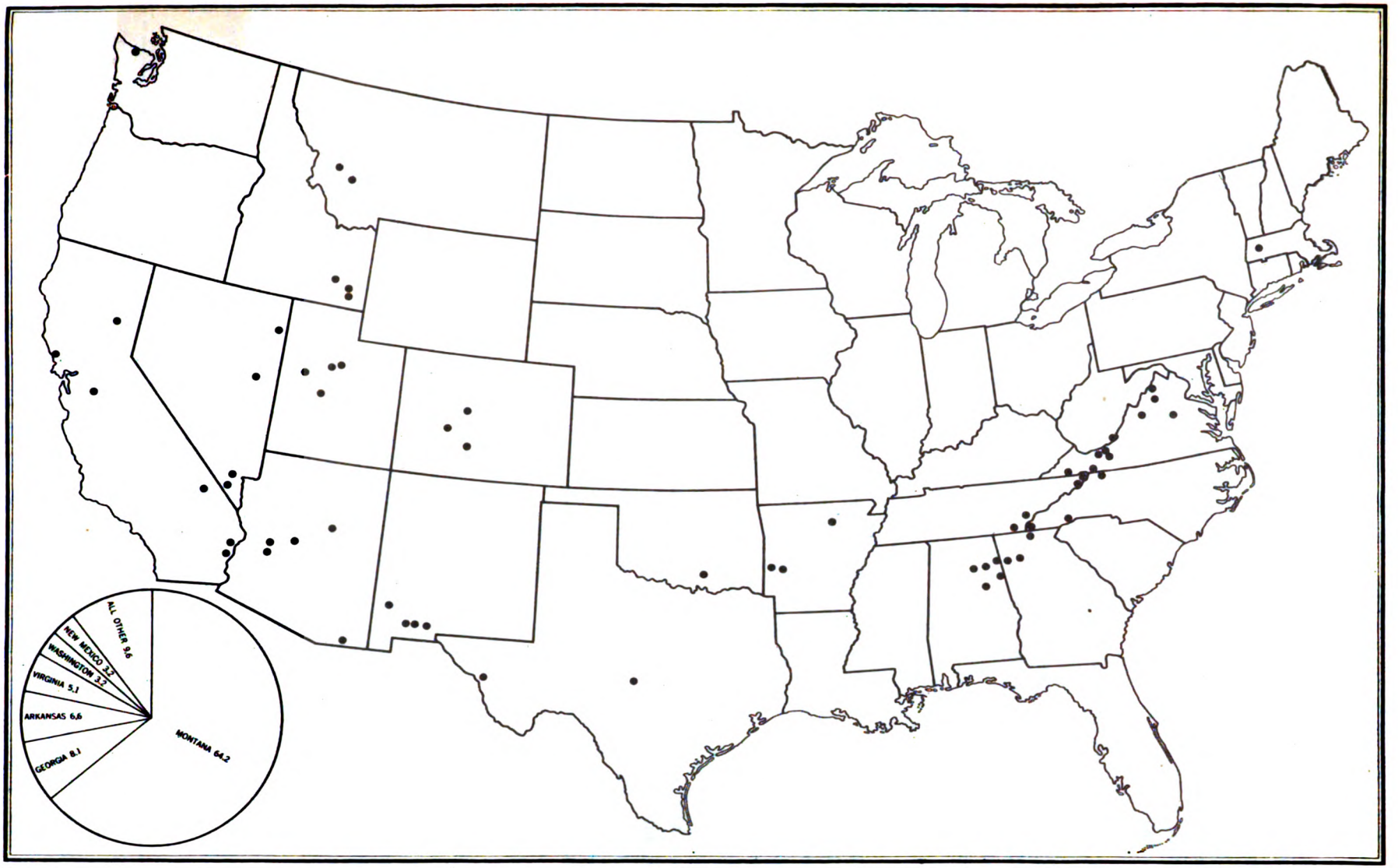

Figure 1.—Localities which have produced manganese ore during the decade 1922–1931 and diagram showing the distribution of production by States during the same decade

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manganese, from the Emma mine at Butte constitutes a large part of the metallurgical manganese ore mined in Montana. The rhodochrosite ore, though relatively low in manganese, has been added to the blast furnace charge for the production of ferromanganese. During the last 5 years, however, flotation and nodulizing processes have been developed which render the rhodochrosite ore into a very high-grade product more suitable for the manufacture of ferromanganese. The nodules produced from raw rhodochrosite ore in 1931 contained 58.8 percent of manganese.

Arkansas, Georgia, New Mexico, and Virginia are the other principal producers of manganese ore.

While the reserves of high-grade ore in the United States are small, there is no dearth of lower-grade raw material. The maximum reserve tonnage of high-grade ore was estimated at 3,000,000 long tons in 1925.[9] This figure may be low for a present-day estimate because of several factors, among which the most important are the application of flotation to certain of the rhodochrosite ores in the Butte district which previously had been considered unavailable for ferrous metallurgy and the further development of reserves in the Philipsburg district due to continued exploitation of the mines.

Because of the strategic importance of manganese, more and more attention is being given to the beneficiation of our low-grade resources. Perhaps the largest single deposit of manganese in the United States is situated near Chamberlain, S. Dak., where the manganese occurs as manganiferous iron carbonate nodules in a horizontal bed of shale 38 feet thick. The deposit extends over many square miles, and estimates indicate that it contains more than 100,000,000 tons of manganese. The average yield per cubic yard of the shale bed is 164 pounds of nodules, having a manganese content of about 25 pounds. This grade of material is much lower than any thus far worked on a commercial scale either in the United States or elsewhere. The separation of the nodules from the shale matrix presents no serious technical problem, as upon exposure to air the shale dries, cracks, and falls away from the nodules. However, the final separation of the manganese from the nodules into a commercial product involves many technical difficulties. The nodules contain about 16 percent of manganese, 11 percent of iron, and are high in phosphorous (0.381-0.548 percent). The manganese is present as an isomorphous mixture of the carbonates of manganese, iron, and magnesium, and is not amenable to concentration by present known means of ore dressing. Various processes for leaching the nodules for their manganese content are being investigated by Sweet and others but to date such processes have not progressed beyond the laboratory stage.

Another large deposit of low-grade manganese ore exists on the Cuyuna Range in Minnesota. There are two general types of manganese-bearing ores in this district designated by Zappfe[10] as black ores and brown ores. The black ores usually contain 15 to 22 percent of manganese and are low in phosphorous and high in silica. The brown ores usually contain about 10 percent of manganese, are lower in silica, and have a high phosphorous content. The brown ores occur in deposits of large tonnage, whereas the black ores are found in narrow bands containing numerous short lenses usually of small tonnages. The reserves of these two classes of ore have been published in 1927 by Joseph[11] as follows: Brown ores, 20,000,000 tons; black ores, 3,500,000 tons. These figures were based on drill records and other in-

9 Mining and Metallurgical Society of America, and American Institute of Mining and Metallurgical Engineers. Report of the Sub-Committee on Manganese. International Control of Minerals: New York, 1925, pp. 51-86.

10 Zappfe, Carl, Manganiferous Iron Ores of the Cuyuna District, Minnesota: Trans. Am. Inst. of Min. and Met. Eng., vol. 71, 1925, p. 374.

11 Joseph, T. L., Barrett, E. P., and Wood, C. E., Minnesota Manganiferous Iron Ores in Relation to the Iron and Steel Industry: Trans. Am Inst. of Min. and Met. Eng., vol. 75, 1927, pp. 304-308.

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formation, and are, perhaps, conservative. Regarding reserves on the Cuyuna range, Zappfe[12] has this to say in part: "Estimates of reserves of such ores have never been made with the same accuracy or diligence as has been made for other grades. I showed in 1927 that in the Cuyuna district alone there was a reasonable safe reserve of 44,000,000 tons; and there remained more to be added if the same allowances were to be made here as is customary in the speculations applied to reserves elsewhere. Furthermore, the study revealed that there need be no fear of running short of this kind of ore, insofar as the present known reserves of iron ore were concerned and after allowing even for an increased use of manganiferous ores." In addition to the black and brown classes of ore, there is an enormous amount of manganese-bearing formation in the Cuyuna district which contains more manganese than the ore previously described but which has a very high silica content. This material contains from 40 to 45 percent (dry) of combined manganese (15 percent or more of manganese) and iron and is low in phosphorous, alumina, and moisture. This material has no commercial application at present, but the brown ores and the black ores have been used for some time in blast-furnace burdens in order to furnish manganese for the pig iron used in making basic steel. Some of the ore has been shipped direct and some has been beneficiated by various processes, the most recent of which is the tabling and flotation process worked out at the Merritt mine of the Manganiferous Iron Co. in conjunction with the Bureau of Mines.[13]

None of the ores shipped from the Cuyuna range have been suitable for the manufacture of ferromanganese, but the large reserves have stimulated research in this direction. The Bureau of Mines has developed a pyrometallurgical method for the production of ferromanganese from the brown ores of this district. This process involves three stages:

1. Smelting of manganiferous iron ore, containing 7 to 15 percent of manganese and 31 to 35 percent of iron (with high phosphorus or silica) in the blast furnace to produce a high-manganese (12 percent) pig iron.
2. Open-hearth treatment of this pig iron to produce steel and a high-manganese (55 percent) slag which can be used as an ore.
3. Conversion of the open-hearth slag to ferromanganese in a blast furnace or electric furnace.

This method has been tried out in experimental equipment and ferromanganese has been produced, but it has not been applied to installations of commercial size.

Wilson Bradley has developed a leaching process to recover the manganese from the black ores and the manganese formation high in silica. In this process the ore is crushed and then roasted in a reducing atmosphere at 750°F. in order to reduce the MnO_2 to MnO and the Fe_2O_3 to Fe_3O_4 with a minimum reduction to FeO. The selective roast renders the manganese soluble while leaving the magnetic oxide of iron insoluble so that it can be later recovered from the residue by magnetic concentration as a by-product iron ore. A solution of ammonium sulphate is then used to dissolve the manganese, forming manganese sulphate, from which the manganese is precipitated as manganous hydroxide by the use of ammonia. This process has been worked out successfully on a laboratory scale and was used at a small pilot plant at the Mines Experiment Station at the University of Minnesota. Other experiments in the concentration of manganese have been made but for the most part have not passed beyond the laboratory stage.

While other deposits of manganese exist in various parts of the country, those which have been noted are considered the most important from the national standpoint.

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12 Zappfe, Carl, Manganiferous Iron Ore in Minnesota: Proc. First Ann. Con. Am. Manganese Producers Asso., 1928. pp. 91-97.

13 DeVaney, F. D., and Clemmer, J. B., Concentration Tests on the Manganiferous Iron Ores of the Cuyuna District Minnesota: Rept. of Investigations 3045, Bureau of Mines, October 1930, pp. 1-9.

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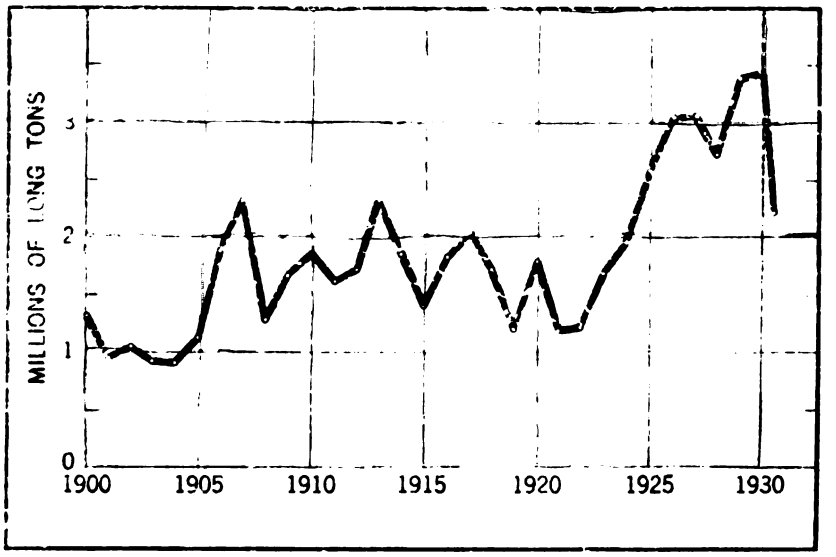

Figure 2.—World production of manganese ore from 1900 to 1931

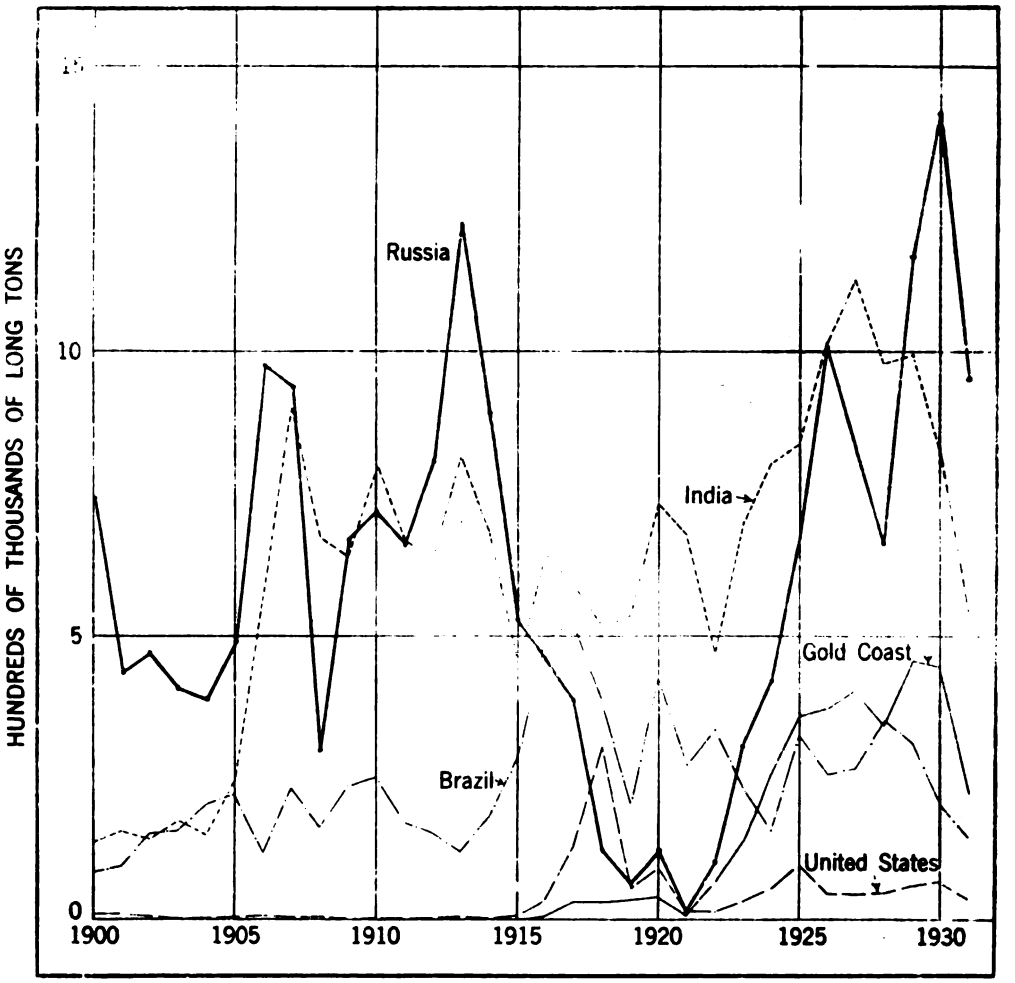

Figure 3.—Production of manganese ore in the main producing countries and the United States from 1900 to 1931

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WORLD PRODUCTION

Although manganese has been used since the time of the Egyptians only a relatively small amount was produced up to the second half of the nineteenth century. During the early part of this period it was used as a decolorizing agent in the manufacture of glass. Later in this period it found further outlets in the ceramic industry and in the manufacture of chlorine. The first application of manganese in metallurgy dates from 1839, when Heath applied manganese compounds to the manufacture of steel. The use of manganese in modern metallurgy dates from 1856 when Bessemer invented the unique process of making steel by the pneumatic method. The first ingots produced by this method in England were red-short and cracked or crumbled in the rolls. Mushet's suggestion of adding spiegeleisen to the blown metal to insure malleability while hot was tried successfully. This discovery established the Bessemer process of making steel, and from then on manganese became essential to steel manufacture.

At this time the higher manganese alloys used in steel manufacture were made by the crucible process and were expensive. The increasing production of steel created a demand for cheaper manganese alloys, and as a result the smelting of spiegeleisen and ferromanganese directly from ores in a blast furnace was developed by Pourcel and others in France from 1875 to 1885. The price of high manganese ferro-alloys was thus greatly reduced and consumption increased greatly. This, in turn, led to an increased demand for high-grade ores. Fortunately this demand was satisfied by the discovery and exploitation of large deposits in Russia (1879), British India (1892), and Brazil (1894). In 1899 world production of manganese ore exceeded 1,000,000 long tons for the first time and has since increased to 3,440,000 tons in 1930.

The production of manganese for the world, principal producing countries, and the United States is shown by years from 1900-1931 in table 2. Figures 2 and 3 show graphically the trends of production in the world and in the important producing countries.

According to the shifting sources during the first three decades of the present century, the production of manganese ore can be divided into three very distinct periods. During the first or pre-war period the world market was supplied very largely by Russia, India, and Brazil; during several years over 96 percent of the world's production was mined in these three countries, the greatest competitors being India and Russia. Russia was the largest producer during most of this pre-war period, but India ranked first in 1908, 1910, and 1911. The production of Russia reached a pre-war peak of 1,225,620 tons in 1913, while India's pre-war production reached a peak of 902,291 tons in 1907.

The character of the manganese world industry changed greatly during the World War. Exports from Russia were stopped, causing a considerable decrease in the production of that country. The production in India also decreased owing to difficulties in ocean transport. Curtailment of supplies from these two countries caused an acute shortage in the world markets, and prices increased greatly. Under this stimulus and owing to the comparatively safe ocean transportation to the war-expanded markets in the United States, Brazil increased its output to a peak of 524,439 tons in 1917. In several other countries, including the United States, production was expanded, but largely from lower-grade deposits.

The third or post-war period was characterized by the return to pre-war sources and the addition of the Gold Coast deposits which were discovered in 1916. The ferruginous manganese ores of Egypt have also increased in importance. The restoration of Russia to its pre-war leadership in manganese production was accomplished in 1929 through a large increase in production, while in the past few years India and Brazil have fallen off. The Gold Coast, however, continues to be an important factor due to the high quality of the ore, cheap mining conditions, and a favorable situation regarding transportation.

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Table 2.- World production of manganese ores during the present century, showing the outputs of the principal producing countries and the United States, long tons

Year	Russia	India	Brazil[1]	Gold Coast[2]	United States	Other	Total[3]
1900	743,169	139,265	86,735	-	11,771	329,060	1,310,000
1901	435,731	157,736	97,267	-	11,995	249,271	952,000
1902	471,013	144,325	154,775	-	7,477	263,410	1,041,000
1903	407,370	177,821	159,369	-	2,825	180,615	928,000
1904	389,709	150,910	204,971	-	3,146	152,264	901,000
1905	489,845	247,427	220,833	-	4,118	159,777	1,122,000
1906	978,536	571,495	119,415	-	6,921	213,633	1,890,000
1907	941,578	902,291	233,038	-	5,604	240,989	2,323,000
1908	297,526	674,315	163,498	-	6,144	128,517	1,270,000
1909	672,275	642,675	236,971	-	1,544	106,535	1,660,000
1910	721,955	800,907	249,942	-	2,258	92,938	1,868,000
1911	662,981	670,290	171,194	-	2,457	104,078	1,611,000
1912	806,918	637,444	152,424	-	1,664	109,550	1,708,000
1913	1,225,620	815,047	120,368	-	4,048	150,917	2,316,000
1914	892,706	682,898	180,729	-	2,635	94,032	1,853,000
1915	529,000	450,416	284,112	-	9,558	126,914	1,400,000
1916	464,371	645,204	495,184	4,258	31,474	199,509	1,840,000
1917	387,059	590,813	524,439	31,136	129,351	378,202	2,041,000
1918	124,333	517,953	387,175	30,291	305,869	352,379	1,718,000
1919	64,563	537,995	202,476	35,189	54,957	300,820	1,196,000
1920	123,321	736,439	428,855	40,970	94,420	367,995	1,792,000
1921	11,763	679,286	271,340	7,195	13,531	199,885	1,183,000
1922	101,857	474,401	335,325	66,113	13,404	219,900	1,211,000
1923	307,728	695,055	232,107	139,634	31,500	291,976	1,698,000
1924	420,085	803,006	156,714	255,343	56,515	263,337	1,955,000
1925	665,820	839,461	326,585	357,165	98,324	298,645	2,586,000
1926	1,012,365	1,014,928	256,240	371,324	46,258	338,885	3,040,000
1927	830,526	1,129,353	269,174	403,187	44,741	379,019	3,056,000
1928	662,765	978,449	353,970	343,246	46,860	343,710	2,729,000
1929	1,165,187	994,279	311,178	457,932	60,379	409,045	3,398,000
1930	1,421,363	829,946	203,564	445,605	67,035	472,487	3,440,000
1931	[4]950,000	537,844	145,021	223,305	39,242	314,588	2,210,000

[1]Exports from 1900 to 1924. [2]Exports. [3]Partly estimated.
[4]Estimate.

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In 1930, world production amounted to 3,440,000 tons, the record production to date. Russia ranked first with a record production amounting to 41 percent of the total. India was second with 24 percent, while the Gold Coast ranked third with 13 percent. Brazil produced 6 percent of the world's total. These four countries accounted for nearly 85 percent of the total output. A more complete list of the sources of manganese ores from 1927 to 1931, inclusive, is shown in table 3:

Table 3.- Manganese ore produced in the principal countries, 1927-1931, long tons

Country[1]	Percentage of manganese	1927	1928	1929	1930	1931
North America:						
Canada (shipments)	-	-	344	269	489	173
Cuba	36-48	799	2,401	957	750	94
Mexico	40+	847	651	245	298	2/
United States-						
Continental (exclusive of fluxing ore)	35+	44,741	46,860	60,379	67,035	39,242
Porto Rico[3]	35+	1,624	1,523	2,316	2,536	2,374
South America:						
Argentina[4]	-	226	139	205	235	-
Brazil	38-50	269,174	353,970	311,178	203,564	145,021
Chile[3]	40-50	7,567	9,047	3,055	6,040	377
Europe:						
Bulgaria	30-45	7	-	-	-	-
Germany	30+	30	207	467	2,312	-
Great Britain	30+	1,031	235	-	-	-
Greece	30+	8,152	1,063	1,575	6,210	350
Hungary	30	16,999	21,817	18,743	8,946	1,114
Italy	30-50	9,610	10,112	9,760	10,465	6,320
Portugal	38-60	483	-	-	-	-
Rumania	42	10,205	30,773	34,485	32,999	18,490
Russia[5]	41-48	830,526	662,765	1,165,187	1,421,363	[7]950,000
Spain	29+	36,288	13,488	17,590	16,553	17,633
Sweden	45+	16,557	15,541	14,378	8,542	8,232
Yugoslavia	42-45	1,940	2,618	3,023	1,515	2,414

[1]In addition to the countries listed Belgium is reported to produce a small quantity of manganese, but statistics of annual output are not available. Czechoslovakia and France report a production of "manganese ore," but as it has been ascertained that the product so reported averages less than 30 percent of manganese and therefore would be considered ferruginous manganese ore under the classification used in this report the output has not been included in the table.

[2]Data not available.

[3]Exports.

[4]Shipments by rail and river.

[5]Year ended Sept. 30.

[7]Estimate.

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Table 3.- Manganese ore produced in the principal countries, 1927-1931, long tons-Continued

Country[1]	Percentage of manganese	1927	1928	1929	1930	1931
Asia:						
China[3]	50-55	45,619	42,648	41,219	53,988	21,702
Cyprus	-	16	-	-	-	-
India-						
British	47-52	1,129,353	978,449	994,279	829,946	537,844
Portuguese	42-50+	[3]2,376	-	-	5,390	3,491
Japan	50+	27,124	17,413	18,155	19,279	-
Netherland East Indies	45-56	18,211	24,066	-	16,426	14,311
Portuguese East Indies (Timor)	-	-	-	3,200	-	-
Turkey	-	11,218	60	149	900	1,000
Africa:						
Algeria[3]	-	3,757	1,453	443	1,558	490
Egypt	30+	150,432	135,331	188,454	119,297	100,174
Gold Coast[3]	50+	403,187	343,246	457,932	445,605	223,305
Morocco (French)	40-50+	[3]2,653	[3]2,110	-	6/	11,320
Northern Rhodesia	41-50	694	1,792	1,849	873	1,467
Tunisia	30-43	2,024	2,165	197	-	-
Union of South Africa	40-60	1,279	-	9,202	144,995	100,290
Oceania:						
Australia-						
New South Wales	-	1,202	167	233	125	-
Queensland	50+	242	-	-	-	-
South Australia	-	-	-	-	-	13
Victoria	50+	15	-	-	4/	-
Western Australia[3]	47+	30	-	80	-	-
New Caledonia[3]	-	128	-	-	-	-
New Zealand[3]	52+	5	-	-	2	-
	-	3,056,000	2,729,000	3,398,000	3,440,000	2,210,000

[1]In addition to the countries listed Belgium is reported to produce a small quantity of manganese, but statistics of annual output are not available. Czechoslovakia and France report a production of "manganese ore," but as it has been ascertained that the product so reported averages less than 30 percent of manganese and therefore would be considered ferruginous manganese ore under the classification used in this report the output has not been included in the table.

[3]Exports.

[6]Estimate included in total.

USES OF MANGANESE ORE

The uses of manganese ore may be considered under two broad classifications: (1) metallurgical, and (2) chemical.

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Metallurgical Uses

Although manganese ore is consumed in both the ferrous and nonferrous metallurgical industries, the bulk of the world's output finds outlet in the manufacture of iron and steel. Various estimates indicate that more than 90 percent of the world's consumption is in the ferrous metallurgical industry. Most of the manganese ore entering this field is used in the making of ferromanganese and spiegeleisen, the forms in which manganese is usually added to steel. These two alloys of iron, carbon, and manganese have the following composition:

	Ferromanganese, percent	Spiegeleisen, percent
Manganese	78–82	18–22
Iron	8–15	70–80
Silicon	0.5–1	1
Carbon	5–7	5–6
Phosphorus	0.1–0.3	0.15
Sulphur, less than	0.03	0.05

Silicomanganese and silicospiegel are used in certain grades of steel and may replace ferromanganese and spiegeleisen. The usual requirements, as to analysis, for these two alloys are:

	Silicomanganese, percent	Silicospiegel, percent
Manganese	55–70	20–50
Iron	5–20	43–67
Silicon	25	4–10
Carbon	0.35	1.5–3.5

Considerable manganese ore is also added to the pig-iron blast-furnace charge when the iron-ore burdens are deficient in manganese, especially when the pig iron is required for steel-making processes.

Under present technology, the use of manganese is indispensable in the manufacture of steel, where it is used to improve blast-furnace operation and to offset the harmful effects of oxygen and sulphur. It is used not only in the process of making plain-carbon steel, but also as an alloying constituent because of certain properties it imparts to alloy steels. Manganese steels are utilized in the manufacture of plates, shapes, structural bars, open-hearth rails, spring steels, car wheels, tires, axles, and for many other purposes where toughness and resistance to abrasion are required. Some manganese is also used in foundry work.

The greater part of the manganese ore mined is used in the manufacture of ferromanganese, either in the blast furnace or in the electric furnace. In the process virtually all of the iron and phosphorus in the charge enters the resultant alloy. Consequently, the usability of the ore depends on the ratio of manganese to iron and on the phosphorus content. The initial requirement of manganese ore is that the ratio of manganese to iron should be about 10 to 1; so that, allowing for normal loss from 12 to 18 percent in the total manganese, the ratio of manganese to iron in the alloy may be maintained. Silica above 8 percent makes ferrograde ores undesirable. The following analyses[14] (table 4) are typical of the general run of foreign ores used in this country for the manufacture of ferromanganese.

14 Langehorne, M. D., Grades and Character of Ore Desired by the Market: Proc. First Ann. Conv. Am. Manganese Producers Assoc., 1928, pp. 124-127.

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Table 4.- Analysis of foreign manganese ores consumed in the United States

Source of ore	Analysis (natural state), percent					
	Manganese	Iron	Silica	Alumina	Phosphorus	Bases
Gold Coast	46.7	6.25	3.15	4.1	0.14	1.50
India	50.51	6.22	8.28	1.83	.09	1.50
Brazil	48.70	4.40	4.60	2.95	.12	2.50
Chile	48.70	.73	9.40	1.69	.008	-
Russia	49.19	.64	7.85	1.57	.22	-

Fine and soft ores are particularly objectionable in blast-furnace practice as they impede the blast and cause loss as flue dust. Hard ore in medium-sized lumps is desired, so that the weight of the charge may be sustained without breakage.

Much lower grade ores are used in the manufacture of spiegeleisen and manganiferous pig iron. Such ores have been classified by the Bureau of Mines as ferruginous manganese ores (Mn content 10 to 35 percent) and manganiferous iron ores (Mn content 5 to 10 percent). Large quantities of ore containing from 2 to 5 percent of Mn are consumed largely in the manufacture of basic open hearth pig. The combined iron and manganese content of such ores, however, should be about 50 percent.

Manganese is also used in the formation of alloys of copper, zinc, aluminum, and other metals. Manganese ores have also been used for fluxing in nonferrous smelting operations.

That there is no extensive use of pure or nearly pure metallic manganese is due in part to the difficulties and high cost of producing the metal. It is consumed largely for experimental purposes.

Chemical Uses

Although the greater part of the production of manganese ore is consumed in the metallurgical industries, many valuable and growing applications of this raw material are found in the chemical industries.

Dry-cell Manufacture.- Probably the most extensive chemical use of manganese ore is in the manufacture of dry cells in which the function of the manganese dioxide is that of a depolarizer. Manganese dioxide used for this purpose should have a high content of available oxygen with minimum iron and be comparatively free from metals such as arsenic, copper, nickel, or cobalt, which are electronegative to zinc. The physical properties of the oxide are important. The material should be porous and moderately hard. Most of the imported material used in dry-cell manufacture in this country contains in excess of 80 percent of MnO_2, but since the war extensive use has been made of domestic material containing about 72 percent of MnO_2 because of its good physical properties. In the United States in the recent past the use of MnO_2 for this purpose has declined with the advent of radio sets which operate on ordinary house current.

Glass Industry.- Another outlet taking advantage of the oxidizing power of manganese dioxide is in the glass and ceramic industry. Most of the sand used in these industries contains iron which imparts a greenish tinge to the glass. The available oxygen of the manganese dioxide converts the greenish salt into the nearly colorless salt, while the slight pink tint imparted by the manganese salt is complimentary to the bluish color of the oxidized iron. Fine glassware is almost entirely decolorized by the addition of manganese dioxide. The quantity of manganese dioxide used varies from 2 to 15 pounds per 1,000 pounds of sand, depending on the character of the glass, the method of its manufacture, the iron content of

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the raw material, the character of the manganese ore used, and the temperature at which the glass is made. Wad, the earthy variety of manganese oxide, is used in conjunction with other oxides in this industry. High-grade ores with a small iron content are required for this trade, although siliceous pyrolusite is not objectionable.

Paint and Varnish Driers.- Manganese compounds are used extensively as driers in the preparation of varnish and paint, due to their catalytic properties. The manganese compounds used are natural and artificial manganese dioxide, manganese hydrate, borate, chloride, sulphate, resinate, linoleate, oxalate, and other salts. Manganese ore required for this use must be of relatively high grade.

Pigments and Dyeing Materials.- Manganese compounds are used in coloring glass, pottery, tiles, and brick; in calico printing and dyeing; and for certain paints. The principal manganese compounds which are used in the color industry are manganese white ($MnCO_3$), manganese green (manganous oxide), manganese violet (manganese metaphosphate), and manganese black (pyrolusite). Wad is used as a constituent of umber paint. Manganese hydroxide and sulphate are used as colors for porcelain and also for the dyeing of textiles. Manganese chloride is used for dyeing cotton to manganese brown or bronze and also in calico printing.

Fertilizer.- Manganese plays a very important part in plant and animal nutrition. The use of manganese in agriculture has been increased in the last few years as a result of some practical demonstrations with truck crops in southern Florida. Most soils contain sufficient manganese for profitable crop production, but in certain sections where manganese is rare in rocks and soils serious difficulties are experienced. The addition of small quantities of manganese sulphate rendered such land productive to crops heretofore considered failures.

Miscellaneous.- Manganese ore is used in the manufacture of iodine and chlorine, but the expansion of the electrolytic process for the production of chlorine has caused a decline in the demand for manganese dioxide for this purpose. Various salts of manganese are used in disinfectants, deodorizers, sterilizing agents, flotation agents, fluxes, medicinal reagents, photographic reagents, and for impregnating leather. The manufacture of the manganates and the permanganates for use as germicides and deodorizers is now an important branch of the chemical industry. The permanganates are also used for the preservation of timber, bleaching of textile fabrics, and as an oxidizing agent in the manufacture of organic compounds.

MARKETING AND PRICE

Of the major steel-producing countries, only Russia has within its national boundaries sufficient manganese ore to supply its needs; all other countries must depend upon imports for their requirements. Consequently, manganese ore is an important strategical commodity in world trade. During the war and immediately after there was a threatened shortage in the supplies of manganese ore due to the restrictions on shipping and later to revolution and internal disturbances in Russia. High prices prevailed during this period. Later, the establishment of more settled conditions in Russia and the advent of new low-cost producers resulted in increasing the supply so that there is now in normal times an oversupply, and sufficient reserves are in sight to insure consumptive industry of an assured supply. Prices declined with the increasing supply.

While there is some small trade in the carbonates and silicates, the principal ores marketed are the oxides. The character of the oxide determines the purpose for which it is used - whether metallurgical or chemical. Metallurgical ore should have a high manganese content (from 45 to 50 percent) and a low content of silica, oxygen, and phosphorus; it may be high in lime. Chemical ores should be high in oxygen, may contain considerable silica and phosphorus, but be low in lime.

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Prices of manganese ore used in the metallurgical industry are quoted on a per unit basis, the unit being 1 percent of a long ton, or 22.4 pounds of metallic manganese. Prices of manganese ore imported into the United States are quoted by the trade journals according to grade and country of origin. According to the Engineering and Mining Journal the trend of prices for imported metallurgical-grade ore was as follows during 1932; the prices are given per long ton unit of manganese c.i.f. North Atlantic ports, exclusive of duty: The trend of prices of ores from all sources was downward during the year. Brazilian ore containing from 46 to 48 percent of manganese was quoted at 23 cents at the beginning of the year but finished the year at 18 cents. Chilean ore containing a minimum of 47 percent of manganese varied from 29 cents at the beginning of the year to 20 cents at the end of the year. The majority of the Chilean quotations were nominal. Indian ore containing 25 to 26 percent of manganese varied from 25 to 26 cents to 20 and 21 cents. Caucasian ore containing from 52 to 55 percent of manganese dropped from 26 cents to 22 cents. South African 52 to 54 percent grade declined from 23 and 25 cents to 20 and 21 cents. The 50 and 52 percent grade was quoted from 23 to 25 cents at the beginning of the year and at 20 and 21 cents at the end of the year. The 44 to 46 percent ore dropped from 21½ cents in January to 18 or 19 cents in December. The manufacturers of ferromanganese commonly select their supplies from various sources in order to get a more favorable furnace burden. Characteristic properties of certain ores are as follows:

High-manganese content	Russian washed ore
Low-phosphorus content	Brazilian or Gold Coast ore
Low-iron content	Russian ore
Low-silica content	Brazilian or Gold Coast ore
Low moisture	Indian ore
Good structure	Indian ore

The trend of prices of metallurgical manganese ore imported into the United States from 1915 to 1932 is shown in figure 4. The prices[15] are given in dollars per long ton of 50 percent manganese ore at North Atlantic ports. From October 1922 through December 1932, two curves are shown; the upper curve is the duty-paid price and the lower curve is the price with the duty unpaid. The figures used in the following discussion are duty-paid prices, as that figure represents the cost of the American consumers. The curve shows that the peak prices occurred during the war period and in July, 1918, reached a maximum of $68.50. With the close of the war the price dropped, until in December 1919 it was given at $27.50. A reaction upward is noted in 1920, but during the slump of 1921 prices fell to $10.50. The application of the tariff of 1922, amounting to $11.20 per long ton on 50 percent ore, was immediately reflected in the price. The tariff increment, combined with an increasing tendency in the price, caused a level in excess of $30 to be reached early in 1923. The price, though declining, remained in excess of $30 until the latter part of 1928, after which a continuous decline brought the price down to $20.70 at the end of 1932.

The lower-grade manganiferous raw materials used in the metallurgical industry are known as ferruginous manganese ore and manganiferous iron ore. The ferruginous manganese ore which contains from 10 to 35 percent of manganese and the manganiferous iron ore which contains from 5 to 10 percent of manganese may be marketed on a unit basis, but as a rule the manganiferous iron ores and the lower-grade ferruginous manganese ores are sold on the total metallic content, - that is, iron plus manganese, based upon the current price of iron ore.

15 Steel, Manganese Ore, 1915-1932: Vol. 92, No. 1, January 2, 1933, pp. 105.

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The chemical industry buys manganese ore on the basis of its content of dioxide, as the oxygen in the ore is the valuable constituent. The ore should be porous and moderately hard. The greater part of this class of ore comes from Russia, the Gold Coast, the United States, Java, and Puerto Rico. The ore is usually sold at a price per long ton with a minimum content of peroxide specified. According to the Engineering and Mining Journal the record of prices for chemical and battery ore during 1932 was as follows: Imported ores (Brazilian, Cuban, Caucasian, Javan) containing from 80 to 85 percent of manganese dioxide were quoted from $50 to $60 throughout the year. Domestic ores containing 70 to 72 percent of manganese dioxide were quoted at $43 to $50 f.o.b. mines.

EXPORTS AND IMPORTS

The bulk of the manganese ore produced in the world is consumed in places distant from the sources of production. The large production is in outlying, less highly developed parts of the world, whereas the consumption is, of necessity, in the highly industrialized regions. Consequently, with the exception of the output of Russia and of smaller amounts in India, virtually all of the manganese ore crosses national boundaries. Furthermore, the long haul and the large tonnages used require that manganese be transported by water. Often the rail haul is the determining economic factor in the development of deposits.

The principal exporting countries are, therefore, the largest producers. Table 5 shows the world exports of manganese ore by countries from 1926 to 1930. The principal exporters during this period were India and the U.S.S.R., each contributing about one third of the world total. India led during most of this period, but in 1929 the U.S.S.R. forged ahead only to drop back again in 1930.

The distribution of exports from the U.S.S.R. for the same period is shown in table 6. The United States was the largest consumer of the ores from U.S.S.R. during the quinquennium. France took important and increasing amounts.

The Indian ores (see table 7) moved to Belgium, France, United Kingdom, and the United States. The bulk of the Brazilian ores moved to the United States, although, as shown in table 8, important quantities were shipped to France and Belgium.

During the four years (1926-1929) shown in table 9, more than 70 percent of the Gold Coast ore moved to Canada, Norway, and the United States. The manganese imported as ores into Canada and Norway reenters the market again in the form of ferro-alloys. France also has taken significant quantities of Gold Coast ores.

Table 5.- World exports of manganese ore by principal exporting countries, 1926-1930, long tons

Country	1926		1927		1928		1929		1930	
	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent
Brazil	314,774	15	238,005	10	356,116	16	288,685	10	189,088	8
Gold Coast	371,324	18	403,187	16	343,246	16	457,932	16	445,605	19
India	613,536	30	843,821	35	834,144	39	964,489	34	773,026	34
U.S.S.R.	622,414	31	771,129	32	499,191	23	1,020,746	36	742,292	32
Other[1]	120,000	6	170,000	7	120,000	6	125,000	4	160,000	7
Total	2,042,048	100	2,426,142	100	2,152,697	100	2,856,852	100	2,310,011	100

[1]Estimates. Does not include export of manganese bearing ores from Egypt.

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Table 6.- Exports of Manganese ore from Russia, by countries, 1926-1930, long tons

Country	1926[1]		1927[1]		1928[1]		1929		1930	
	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent
Belgium	81,603	12	70,926	9	64,868	13	74,759	7	13,999	2
France	40,251	6	79,425	10	63,513	13	117,800	12	115,105	15
Germany	41,600	6	71,803	9	43,366	9	47,377	5	91,252	12
Italy	32,156	5	31,974	4	45,612	9	56,357	6	61,791	8
Netherlands	100,719	16	240,928	32	44,243	9	-	-	44,888	6
Poland	23,133	3	21,023	3	30,333	6	38,900	4	24,849	3
United Kingdom	68,746	10	25,741	3	12,966	3	64,391	6	14,558	2
United States	274,157	42	211,140	29	186,102	38	395,025	38	182,989	25
Other	-	-	7,522	1	-	-	226,137	22	192,861	27
Total	662,365	100	760,482	100	491,003	100	1,020,746	100	742,292	100

[1]Fiscal year ending September 30.

Table 7.- Exports of manganese ore from India, by countries 1926-1930, long tons

Country	1926		1927		1928		1929		1930	
	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent
Belgium	185,974	30	174,485	21	183,897	22	181,174	19	98,205	13
France	151,906	25	151,100	18	195,576	23	219,055	23	208,887	28
Germany	6,346	1	12,805	2	20,945	3	12,630	1	24,360	3
Italy	9,600	2	5,150	1	9,475	1	4,246	0	620	0
Marmagoa[1]	89,620	15	162,378	19	175,577	21	184,939	19	170,577	22
Netherlands	14,800	2	12,500	1	7,501	1	36,350	4	11,500	1
United Kingdom	74,750	12	211,401	24	159,227	19	264,537	28	164,895	21
United States	67,250	11	97,500	12	76,000	9	51,250	5	54,000	7
Other countries	13,290	2	16,502	2	5,946	1	10,308	1	39,982	5
Total	613,536	100	843,821	100	834,144	100	964,489	100	773,026	100

[1]Some Indian ore is exported via Marmagoa, Portuguese East Africa. Details as to the destination of this ore are not available.

Table 8.- Exports of manganese ore from Brazil, by countries, 1926-1930, long tons

Country	1926		1927		1928		1929		1930	
	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent
Belgium	11,340	4	53,345	22	60,318	17	30,631	11	2,329	1
France	9,821	3	25,706	11	54,897	15	29,962	10	10,926	6
United States	287,573	91	158,638	67	222,727	63	228,092	79	175,666	93
Other	6,040	2	316	0	18,174	5	-	-	167	-
Total	314,774	100	238,005	100	356,116	100	288,685	100	189,088	100

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Table 9.- Exports of manganese ore from the Gold Coast, by countries, 1926-1930, long tons

Country	1926		1927		1928		1929		1930	
	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent	Quantity	Per-cent
Belgium	13,889	4	29,872	7	12,565	4	62,813	14	(1)	-
Canada	49,276	13	67,689	17	53,356	15	85,751	19	(1)	-
France	19,606	5	68,593	17	78,566	23	85,944	19	(1)	-
Norway	141,826	38	157,726	39	139,444	41	169,722	37	(1)	-
United Kingdom	32,635	9	619	0	3,806	1	1,523	0	(1)	-
United States	111,990	30	78,688	20	53,464	15	50,597	11	(1)	-
Other	2,102	1	-	-	2,045	1	1,582	0	(1)	-
Total	371,324	100	403,187	100	343,246	100	457,932	100	445,605	-

[1]Not available.

The United States draws largely on imports for its necessary requirements of manganese ore; the U.S.S.R., Brazil, and the Gold Coast furnish the principal amounts which in 1931 accounted for 83 percent of the total imports. Details of the imports of manganese ore into the United States from 1927 to 1931 are shown in table 10:

Table 10.- Manganese ore imported into the United States by countries, 1927-1931, long tons

Country	1927	1928	1929	1930	1931
Union of South Africa	-	5	-	-	5,002
Gold Coast	87,230	24,186	33,593	93,142	87,439
Brazil	174,026	142,300	216,535	185,048	133,927
India British	93,017	83,600	72,940	58,150	47,850
Canada	430	3,929	4,804	15,998	18,832
Chile	3,206	9,340	2,000	3,485	1,748
Cuba	8,976	3,180	2,667	2,071	3,804
Egypt	-	-	101	-	-
Germany	65	133	1,137	66	30
Italy	-	-	71	-	-
Java and Madura	1,527	1,026	1,000	1,602	1,754
U.S.S.R.	253,544	159,842	329,336	225,888	195,834
United Kingdom	46	167	85	109	6,298
Other countries	-	-	-	9	-
Total	622,067	427,708	664,269	585,568	502,518

Although the United States is the largest producer of steel, during the 5 years ending 1931 it was second in imports of manganese ore. France imported more ore during this period, but its production of steel amounted to only 14 percent of the American output. India and the U.S.S.R. are the principal suppliers of French imports. Recent reports indicate that France is developing manganese resources within the French Empire in order to become independent of foreign supplies. Details of the French imports of manganese ore are shown in table 11:

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Table 11.- Manganese ore imported into France by countries, 1927-1931, long tons

Country	1927	1928	1929	1930	1931
Brazil	22,174	42,489	70,532	16,428	3,832
India British	257,077	262,877	272,512	288,512	132,891
Gold Coast	31,984	77,203	101,107	82,551	30,579
Spain	40,546	13,031	18,969	21,370	1,565
U.S.S.R.	77,508	108,667	181,132	189,021	134,816
Other countries of Asia	34,979	41,793	36,294	12,701	30,476
Other countries	184,904	180,511	107,050	93.175	139,494
Total	649,172	726,571	787,596	703,758	473,653

Great Britain draws most of its manganese ore from within the Empire, India furnishing the principal amounts. In 1931 imports of manganese ore from India amounted to nearly 80 percent of the total British imports. Table 12 shows the imports into the United Kingdom by countries of origin from 1927 to 1931.

Table 12.- Mananese ore imported into the United Kingdom by countries, 1927-1931, long tons

Country	1927	1928	1929	1930	1931
Brazil	1	8,010	-	-	-
Gold Coast	505	1,319	1,380	2,297	5,238
India	176,757	175,378	259,260	184,326	62,168
Java	1,973	1,998	1,361	1,225	1,675
Netherlands	197	583	629	413	357
Marmagoa	-	13,005	11,256	10,323	-
Spain	3,291	-	2,289	1,270	742
U.S.S.R.	13,061	1,750	10,046	8,401	1,606
Other	2,742	3,922	3,132	8,189	6,479
Total	198,527	205,965	289,353	216,444	78,265

Germany imports most of her requirements from the U.S.S.R. India furnishes important amounts, and there is some import of the ferruginous manganese ores of Egypt. The details of German imports are shown in table 13.

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Table 13.- Manganese ore imported into Germany by countries, 1927-1931, long tons

Country	1927	1928	1929	1930	1931
Brazil	2,529	27,372	3,617	523	-
India British	75,431	124,594	128,485	77,116	23,016
Gold Coast	(1)	(1)	(1)	328	234
Netherlands	6,133	12,567	7,765	3,749	3,457
Egypt	46,092	29,489	35,044	17,208	11,015
Russia in Europe	(1)	(1)	(1)		
Russia in Asia	207,312	71,060	175,933	170,921	109,697
Other countries	29,567	14,669	30,421	60,233	12,378
Total	367,064	279,751	381,265	330,078	159,797

[1]Included under other countries.

India furnished the larger part of the manganese ores imported into the Belgium-Luxemburg Economic Union during 1927 to 1931. These amounts, however, were supplemented by important receipts principally from the U.S.S.R. Further details are shown in table 14:

Table 14.- Manganese ore imported into the Belgium-Luxemburg Economic Union, 1927-1931, long tons

Country	1927	1928	1929	1930	1931
Brazil	-	37,752	18,263	1,551	-
Egypt	980	-	-	(1)	-
France	-	-	-	16,108	12,797
Gold Coast	-	-	-	7,727	1,358
India British	94,857	122,977	149,868	117,198	98,848
Portuguese India	-	12,611	19,270	17,895	9,866
U.S.S.R.	75,183	68,254	87,610	64,524	96,833
Other countries	94,090	21,333	48,466	30,540	18,596
Total	265,110	262,927	323,477	255,543	238,298

Imports into Norway and Canada come largely from the Gold Coast.

POLITICAL AND COMMERCIAL CONTROL

Political Control

Of the record world production of manganese ore in 1930, 86 percent originated in two political units: The British Empire (45 percent) and the U.S.S.R. (41 percent). Brazil contributed 6 percent and the remaining 8 percent came from various other countries throughout the world.

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Commercial Control

The bulk of the world's output in 1930 was controlled by three groups -- Russian, British, and American. The Soviet Union, through its control of the deposits at Chiaturi and Nikopol, was responsible for more than 41 percent of the world's production of manganese ore in 1930. British interests controlled about 32 percent, chiefly in India, the Union of South Africa, and Egypt. American firms controlled 20 percent by virtue of their operations in the Gold Coast and in Brazil. The Brazilian properties are controlled through a subsidiary corporation, whereas in the Gold Coast the American firms operate under lease from British fee owners.

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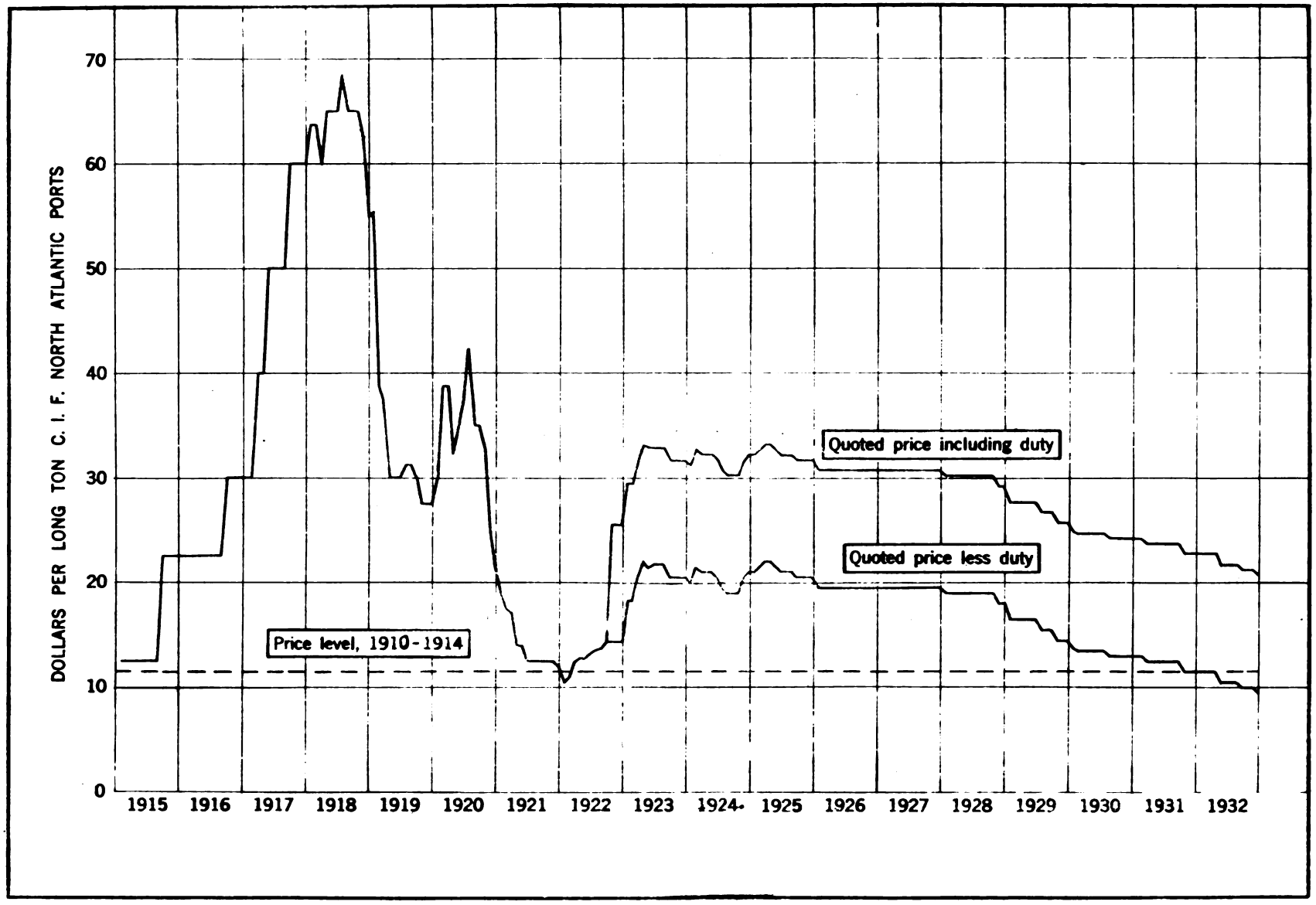

Figure 4.—Price of 50 percent manganese ore imported into the United States from 1915 to 1932.

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